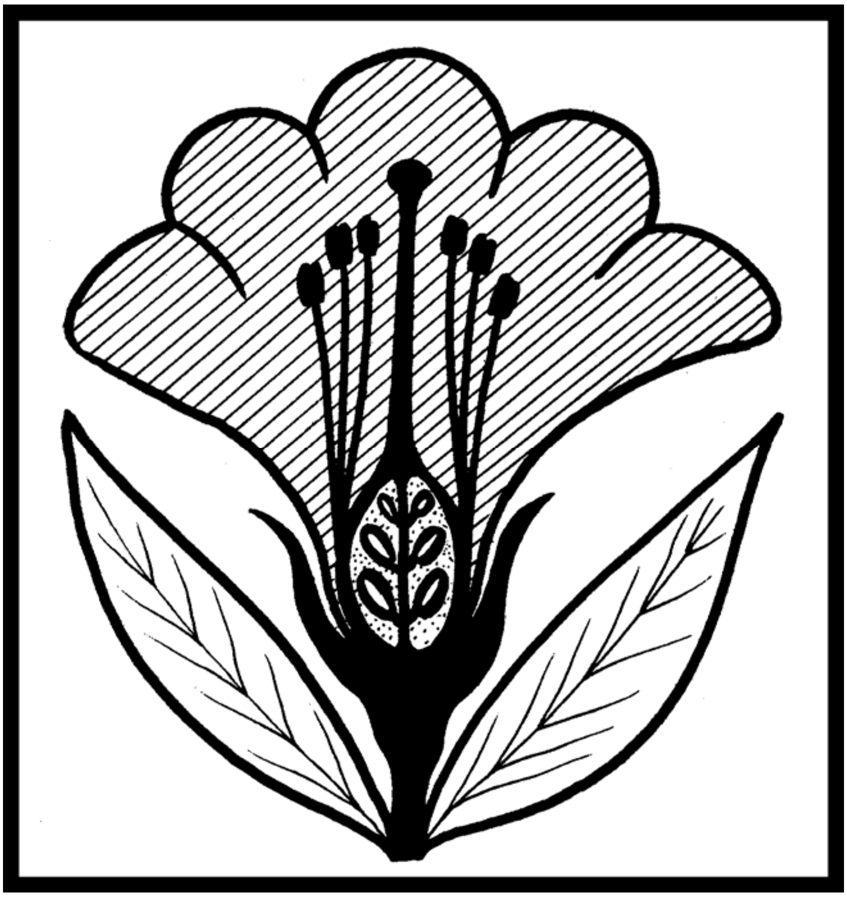
NR Study-note 120a

AN OUTLINE OF TREE SEED BIOLOGY



Based on the text and graphics in:
AN OUTLINE OF TREE SEED BIOLOGY
With special reference to seed handling in Nepal.
Technical Note no. 6
HMG/EEC/ODA National Tree Seed Project
by A.M.J.Robbins (1987)

Revised July 2004

PREFACE to the original publication

For ever-increasing afforestation programmes, obtaining supplies of high quality, healthy seeds has been a great problem. This is made more difficult as we use large numbers of different species to meet the preferences of the local people as well as to suit ecological requirements. The HMG/EEC/ODA. 'National Tree Seed Project' began in early 1987. Its purpose is to assist the districts in ensuring adequate seed supplies for the afforestation programmes, as seeds are the most essential basic resource material for raising successful plantations. Better and healthy seeds grow into better seedlings which ultimately will grow into healthy trees. Therefore this publication will fulfil the long felt need in seed biology. I very much appreciate and am also indebted to Mr. Marcus Robbins, the T.C.O. who took so much pain and time in preparing this publication. I am sure all concerned will benefit from it.

N.B.Shrestha
Project Chief
National Tree Seed Project
November 1987

INTRODUCTION to the original publication

This technical note provides an outline of the biological principles behind the various practices of tree seed handling, so that they may be carried out with a better understanding of why they are done.

It is not intended to be a detailed treatise (for which there are many good texts available), but rather a means by which forest officers can refresh their memories as to the principles, and provide a framework within which they can expand their knowledge, when necessary.

The technical note is intended to complement the Tree Seed Handling Manual produced by NTSP/CFDP which covers field practices of seed collection, processing, storage and testing. Particular reference has been made to species in Nepal, but the general principles apply to anywhere.

It is assumed that forest officers wishing to read this technical note will have a working knowledge of English, and therefore it has not been translated into Nepali. The Tree Seed Handling Manual is, however, in both languages

I am very grateful to Mr. J.K.Jackson and Dr. P.B.Tompsett for their comments on the draft manuscript.

A.M.J.Robbins
Kathmandu
October 1987

NOTE on the current publication

The original publication has been reformatted here, in electronic form, with some modifications, as a follow-up to a study commissioned by FAO, to make tree seed extension literature more widely available. I am very grateful to Pierre Sigaud at FAO for his original initiative and support in doing this. The current version is one in a series of NR Study-notes produced by the author, for use in training courses.

The document may be freely edited, provided acknowledgement of the source is made. The graphics are available in TIFF format for editing, if required. A version of the original publication is available in Arabic from FAO.

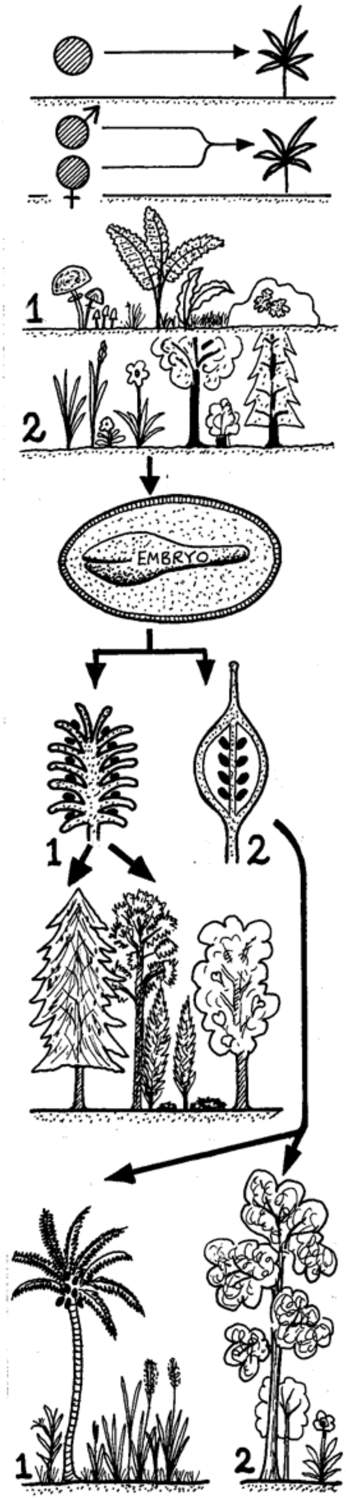
Please send any comments or requests to: marcus.robbins@virgin.net
A.M.J.Robbins
Oxford
July 2004

VERSION July 2004

SUMMARY OF CONTENTS

Scientific names of species mentioned in the text.

Bainsh	*Salix spp*
Bakaino	*Melia azadarach*
Banyan	*Ficus benghalensis*
Champ	*Michelia champaca*
Chir Pine	*Pinus roxburghii*
Khasru	*Quercus semicarpifolia*
Kimbu	*Morus alba*
Lankuri	*Fraxinus floribunda*
Lapsi	*Choerospondias axillarias*
Lahar pipal	*Popular deltoides*
Paingyo	*Prunus cerasoides*
Sal	*Shorea robusta*
Sallako rukh	*Conifer spp.*
Pipal	*Ficus religiosa*
Sissoo	*Dalbergia sissoo*
Siris	*Albizzia spp.*
Utis	Alnus nepalensis



1 SEEDS AND PLANTS

1.1 New plants from old:

The offspring of plants start life as single cells called **spores**. In some plants, one spore can form a new plant by itself (**asexual reproduction**), but in most plants (as in man) two distinct **male** (♂) and **female** (♀) spores are needed to form a new plant (**sexual reproduction**).

1.2 Plants with and without seeds:

Plants can be divided into two main groups, according to spore types (1) Plants with simple spores (**Sporophytes**) e.g. algae, mosses, ferns. fungi. (2) Plants with more complex spores, and which form a seed during development of the new plant (**Spermatophytes**) e.g. grasses, herbs, trees.

1.3 A plant in a package:

A seed is basically a resting stage in the development of the new plant. It consists of a very young plant (**embryo**), packed in such a way that it can be transported away from the mother plant, and resume growth in another area when conditions are suitable.

1.4 Exposed and enclosed seeds:

Plants that have seeds are themselves divided into two groups: (1) Plants that have their seeds exposed on top of scales (**Gymnosperms**) e.g. pine, larch. (2) Plants that have their seeds enclosed in a case or **ovary** (**Angiosperms**) e.g. grasses, paingyo, utis.

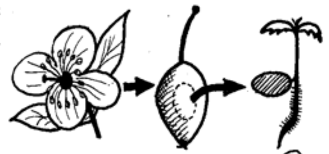
1.5 Plants with exposed seeds:

The Gymnosperms are divided into 4 classes of which the most important includes the **conifers** e.g. pine, fir (sallako rukh). They are sometimes called *'evergreen'* or *'softwood'* trees, but this is inaccurate as some are not evergreen, and many do not have softwood. Another class includes the **Gingko** tree.

1.6 Plants with enclosed seeds:

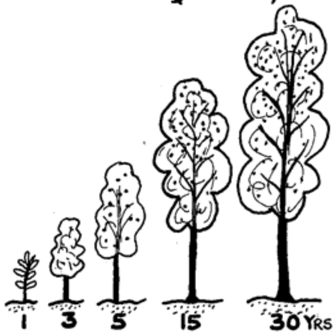
The Angiosperms are divided into two classes: (1) Plants that have seeds with only **one seed-leaf** or **cotyledon** (**Monocotyledons**). The adult leaves are usually long and narrow with parallel veins e.g. grasses, cereals, palms. (2) Plants that have seeds with **two cotyledons** (**Dicotyledons**). Most trees that are not conifers belong to this type. They are sometimes called *'broadleaved'*, *'deciduous'* or *'hardwood'* trees, but these names are inaccurate as some have narrow leaves, are evergreen, or may have soft wood.

2 FORMATION OF FLOWERS



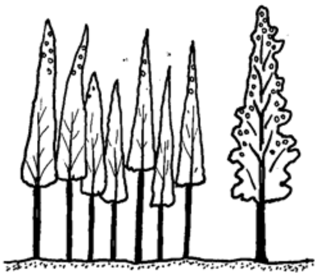
2.1 Flowers, fruits and seeds:

Seeds are found within fruits which form from flowers. A knowledge of how seeds form must therefore start with an understanding of how flowers form and function.



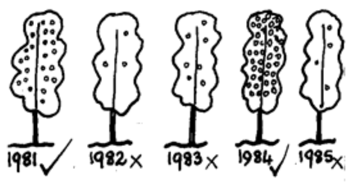
2.2 Age of flowering:

Most trees will not start to flower until they are 5 years old or more. Some may produce a few flowers at a younger age. Once the flowering phase starts, a tree will continue to flower throughout its life, but the amount of flowers will be reduced when the tree becomes over-mature.



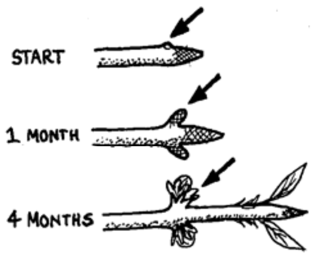
2.3 Conditions for flower formation:

Once a tree is mature enough to produce flowers, environmental conditions will determine whether it flowers or not. In general, trees must have adequate moisture, light, temperature and nutrients for abundant and re.g.ular flower formation. Trees grown close together will form fewer flowers than those grown further apart. This is illustrated by trees growing at the edge of a plantation, which produce more flowers than those inside.



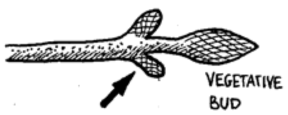
2.4 Frequency of flowering:

Many species will flower abundantly every year. However, some species tend to flower profusely in cycles, every 2 - 4 years or more (*periodic flowering*) or the flowering may be irre.g.ular, with unpredictable good and bad seed years e.g. pine. A few species (some palms, bamboos) flower once in their lives and then die.



2.5 Time taken for formation:

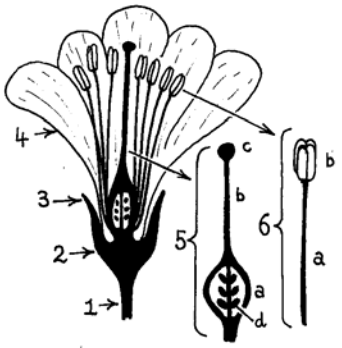
A flower starts to form many weeks or months before it is visible as a flower bad. It is then that conditions must be right for formation as mentioned above. Once the buds are developed, they may rest for several months (e.g. over-winter) before they open and form mature flowers. The time depends greatly on weather conditions, particularly temperature. Once opening be.g.ins, it is usually quite quick.



2.6 Recognising flower buds:

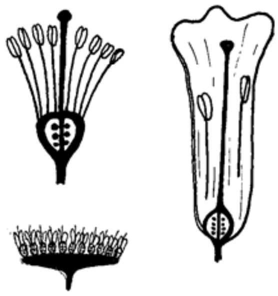
Flower buds can often be distinguished from buds that produce stems or leaves (*ve.g.etative buds*). They generally appear further back on twigs, rather than at the end, and are often more rounded in shape than ve.g.etative buds.

3 FLOWER STRUCTURE



3.1 Flower parts:

Flowers of Angiosperms consist of same or all of the following parts: (1) a stalk (**pedicel**); (2) a base (**receptacle**). (3) old bud scales (**sepals and bracts**). (4) **petals**; (5) one or more female organs (**carpels**), consisting of (a) a hollow container (**ovary**), on top of which is (b) a stalk (**style**), ending in (c) a sticky tip (**stigma**). The carpels may be fused to form one **pistil**. Enclosed within the ovary are (d) the potential seeds (*ovules*); (6) male organs (**stamens**) each consisting of (a) a thin stalk (**filament**) which ends in (b) a cluster of two or four *sacs* (**anther**), within which are found a yellow dust (**pollen** grains).

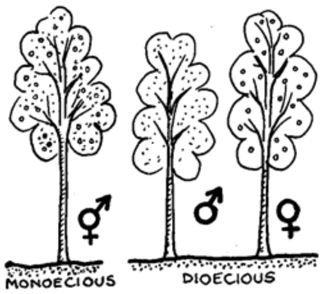


3.2 Arrangement of parts:

These parts are arranged in many different ways, depending on the species. Sometimes parts are missing; the receptacle nay be small and round or large and disc-shaped; the petals can be almost any colour; the number of petals, carpels and anthers can vary greatly in number; sometimes parts are fused together; the ovary may be located low or high within the flower**.** The arrangement of parts is fixed within a species, and is so distinctive that it is useful for identifying species.

3.3 Male and female flowers:

Some species have flowers which contain both male and female organs (**perfect** flowers) e.g. cherry. Other species have separate male and female flowers. Only stamens are found in the male ones, and carpels in the female ones (**imperfect** flowers) e.g. alder.



3.4 Male and female trees:

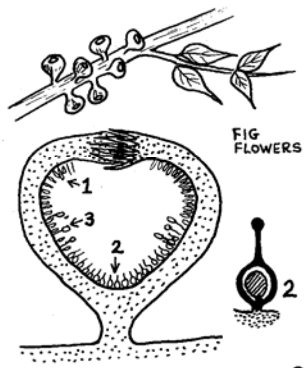
Species that have separate male and female flowers can have them on the same tree (**monoecious** species) e.g. alder. However, some species are like man, and there are distinct male and female trees. The male trees produce only male flowers, and the female only female flowers. Only the female trees will produce fruits and seeds (**dioecious** species) e.g.lahare pipal, some figs.

3.5 Grouping of flowers:

Flowers can grow singly over the tree, or in groups (**inflorescence**). The main stalk of a group of flowers is the **peduncle**. The position of the flowers on the peduncle will determine the shape of the inflorescence, e.g. spike, umbrella or conical shaped. Some flowers do not have stalks (**sessile** flowers) and are attached directly to the peduncle or branch (e.g. catkins). Some inflorescences are very compact and look like one flower, but in fact consist of many tiny flowers.

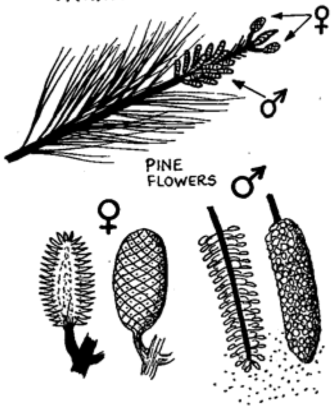
3.6 Position of flowers:

Flowers or groups of flowers can be found growing at the end of branches e.g. Callistemon or further back on the side shoots e.g. lapsi, or even from the branch or stem itself e.g. figs. Flowers tend to be most prolific towards the top of the tree. The position and grouping of the flowers determines the arrangement of fruits, and hence the correct way in which the fruits can be harvested. It is important to know where the flower buds form, so that future seed crops are not damaged while harvesting the current crop.



3.7 Fig flowers:

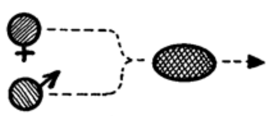
Figs are angiosperms, but have very special flowers. They are of three types: (1) male, (2) female and (3) **gall** flowers. Within the gall flowers live tiny <u>wasps</u> which pollinate the female flowers. The flowers are very small, and grow within a fleshy cup or fig. Some species have all types of flowers within the one fig (e.g. pipal, banyan - usually strangler species). Other species are dioecious, and have male and gall flowers inside each fig on male trees, and female flowers inside each fig on female trees.



3.8 Conifer flowers:

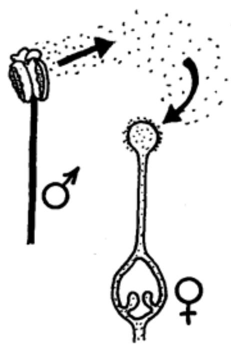
Conifers (Gymnosperms) have separate male and female flowers which are mach simpler than Angiosperm flowers. The male flowers (<u>**strobilus**</u>) consist of a central stalk, from which many scales grow. Each scale has two pollen sacs. The whole flower looks like a catkin when mature. The female flower (<u>**conelet**</u>) also consists of a central stalk, to which many scales are attached. On the surface of each scale there are two ovules. These are exposed and not contained in an ovary. Conifers can be monoecious e.g. pine,or dioecious e.g. juniper.

4 FLOWER FUNCTION



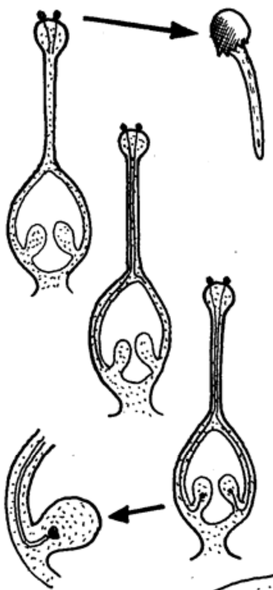
4.1 The start of the seed:

A seed starts to form once a male reproductive cell (**gamete**) has joined a female gamete. Flowers are designed to achieve this process, which begins once the flowers mature and open.



4.2 Pollination:

The male gamete is found within the pollen grains which are formed by the anthers. When ripe, the pollen sacs split open and the pollen is released. The pollen is then transported (by wind or insect) to a female organ of the same species. On arrival, the pollen sticks to the stigma of the pistil/carpels). This process is called pollination.



4.3 Fertilisation:

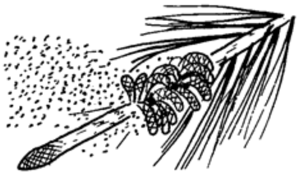
The pollen grains then germinate, and each one sends a root-like growth (pollen-tube) down the style, which grows in search of a female gamete or **ovum**. When a pollen tube reaches the ovary, it grows towards an ovule, enters it via a small opening (**micropyle**), and then finds the ovum. The male gamete, which is at the tip of the pollen tube, then fuses with the ovum. This fusion is called **fertilisation**

4.4 One ovule: one pollen grain:

Most flowers have ovaries within which are several ovules. Each must be fertilised by one pollen grain to produce a seed. Therefore many pollen grains must stick to the stigma, and grow in search of the ovules. Once an ovule is fertilised, new pollen tubes will not grow towards it, but find another unfertilised ovule.

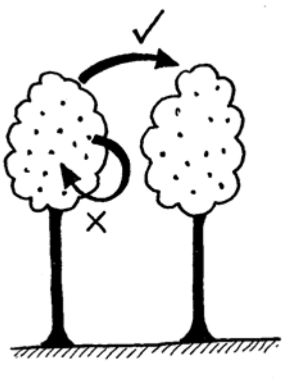
4.5 Pollination by insects:

In flowers that are pollinated by insects (or other animals), the petals are usually large, coloured, and sweet-smelling. This attracts the insects to a sweet sap contained within the flower which the insect uses as food (e.g. as with bees). Whilst feeding among the flowers, the insects pick up pollen from the anthers and transfer it to the stigma of another flower when it flies to it e.g. paingyo.



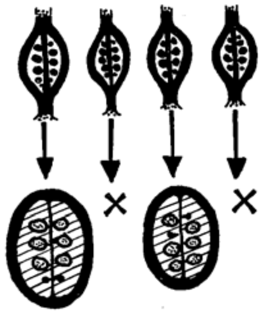
4.6 Pollination by wind:

Flowers that are pollinated by wind are often inconspicuous because they do not need to attract animals. The wind simply distributes the pollen into the air, and eventually some of the pollen grains land on a stigma. Plants with wind pollinated flowers must produce much more pollen than insect pollinated species, since much will be wasted e.g. utis.



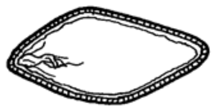
4.7 Cross and self pollination:

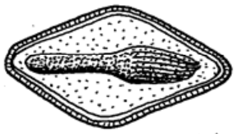
Ovules generally form healthier seeds with vigorous embryos if they are fertilised by pollen from a different tree of the same species (**cross pollination**). Ovules that are fertilised by pollen from the same tree (**self pollination**) tend to produce weaker seeds (because of genetic reasons). Therefore, flowers are often designed to avoid pollination by the same tree. This is done in various ways such as: chemical control; variation in maturity of male and female parts; special shapes of flowers; male and female trees (dioecious species).



4.8 Poor pollination:

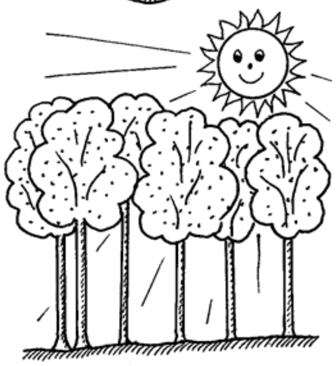
Pollination must be adequate for proper development of fruits and seeds. If an ovule is not fertilised, it will not usually form a seed. If only a few of the ovules within an ovary are fertilised, the flower may not form a fruit and fall off (**abort**). Inadequate pollination may occur for reasons such as: insufficient pollen was produced; weather conditions prevented the pollen reaching or growing on the style; or too much pollen came from the same plant.





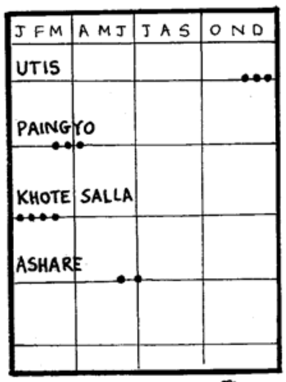
4.9 Empty seed:

Sometimes an ovule is fertilised, but an embryo plant is not formed. If this happens, an empty seed may develop. This often happens if self-pollination occurs, and for this reason fruits collected from very isolated trees may contain many empty seeds. It is difficult to give a rule which defines what is an isolated tree, as this depends on the efficiency with which pollen is transported between trees.



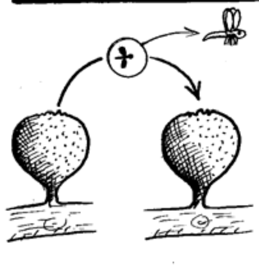
4.10 Conditions for good pollination:

Good pollination is thus necessary before plenty of fruits can form with viable seeds inside. The conditions that will give this are: abundant flowering and pollen formation; good weather (usually warm and dry); sufficient number of parent trees producing pollen (to reduce self pollination). In general it is always best to collect fruits during abundant crops, as it is not only cheaper, but the fruits will tend to yield more and better seeds.



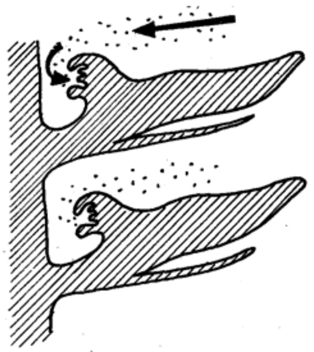
4.11 Flowering seasons:

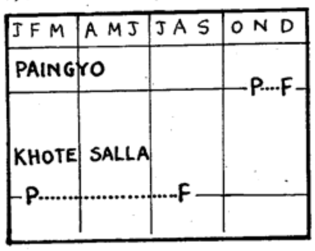
Flowering often occurs during the dry season when conditions are best for wind pollination, but it may be at any time for insect pollinated flours. Individual flowers on the same tree usually mature within a few days of each other. They will stay open for several days or weeks until pollination is complete. The flowering period of a group of trees may be spread over several weeks or months due to differences in the flowering times of individual trees. The actual start of the flowering season may be delayed or brought forward depending on weather conditions. Flowering is generally later if temperatures are cooler (e.g. at higher altitudes).



4.12 Fig pollination:

The flowers within a fig are pollinated by a wasp which lives almost all its life inside the fig. Each species of fig needs a particular species of wasp for pollination, and if it is not available, seeds will not be produced.



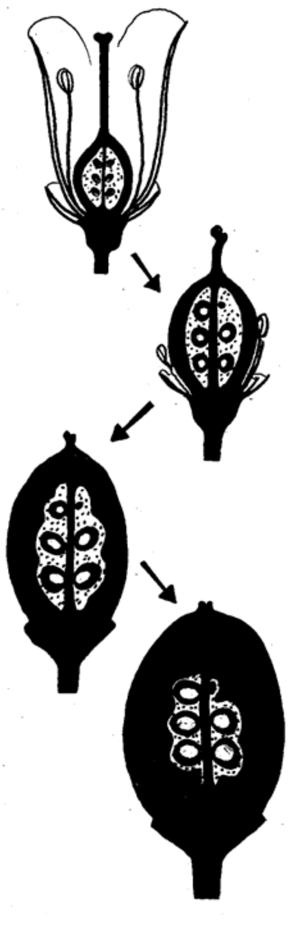


4.13 Conifer flowering:

Although the basic process of pollination and fertilisation is the same in conifers, there are some points to note. All conifers hare separate male and female flowers which are wind pollinated. Since the ovule is exposed, pollen grains land directly on the ovule which exudes a sticky substance near the micropyle. The pollen tube grows directly through the micropyle. The actual process of fertilisation is slightly different, but practically the same.

4.14 Time taken until fertilisation:

The time taken between pollination (P) and fertilisation (F) varies considerably between species. In some species e.g. utis, it may take a few hours, whilst in others it may take as long as several months (e.g. pine) - well after flowering has taken place.



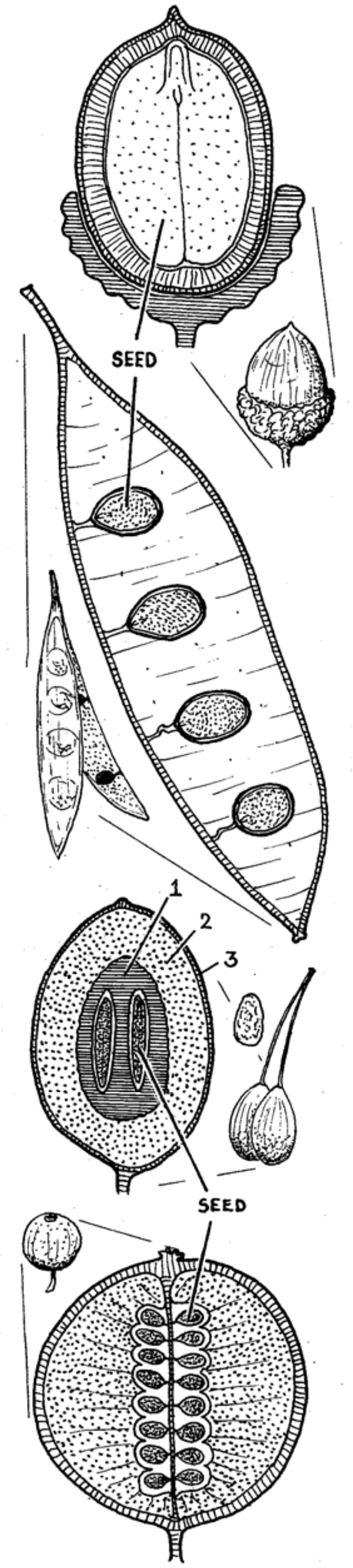
5 FRUIT DEVELOPMENT

5.1 Flowers to fruits:

Once fertilisation has taken place in a sufficient number of ovules, the fruits and seeds within can begin to develop. The fused gametes (fertilised ovum) will grow to form the embryo plant, whilst the other parts at the ovule form the nutritive tissues and coat of the seed. The ovary will develop to form the fruit in which the seeds are contained. The process differs somewhat between gymnosperms and angiosperms, but is basically similar.

5.2 Angiosperm fruit types:

Once fruit development starts, various changes occur to the flower. The sepals and petals usually fall off, and the stamens and styles wither away. Male flowers that only have stamens will fall off, and only the female flowers will remain. The ovary then swells up, and sometimes the receptacle, too. The fully developed ovary that surrounds the seed is called the **pericarp**. The final form of the fruit depends on the original flower type. For the purposes of seed handling, mature fruits can be classified into four main types.



5.3 Dry fruits that do not open:

In this type, the ovary and the seeds within (usually one) grow together and become fused, so that they are not easily separated e.g. acorns, nuts, achenes. Sometimes, parts of the flower or ovary develop and form a distinctive part of the fruit e.g. the husk (**involucre**) of teak; the wings of sal fruits; the cups of acorns. When mature, these fruits are fairly dry and not juicy. Such fruits are generally sown complete, since the seed cannot be separated. Hence they should be called fruits, and not seeds as is often done.

5.4 Dry fruits which open:

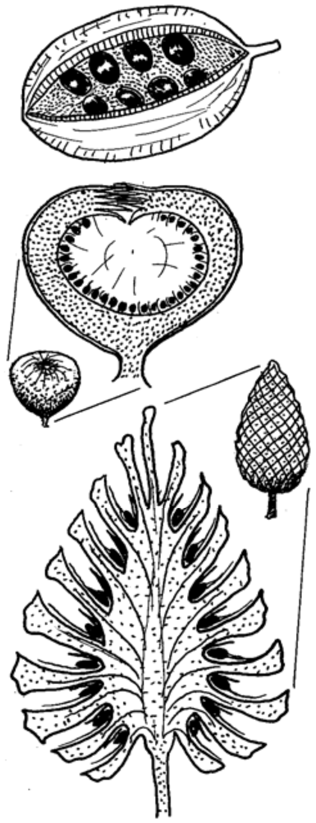
In this type, the ovary develops to form a hollow container in which are found several seeds, loosely attached to the ovary wall. When the container is fully mature and dry, it splits open to reveal the seeds which are distributed by various means. The container may split down one side (**follicle**); two sides (**pod or legume**), or three or more sides (**capsule**). The seeds are easily separated and used as true seeds.

5.5 Fleshy fruits with stones:

In this type, the ovary forms a pen-carp which consists of three distinct layers: (1) the part immediately around the seeds develops to form a hard bony 'stone' or 'pit' (**endocarp**); (2) around the stone, a fleshy juicy layer develops (**mesocarp**), which is protected by (3) a thin skin (**epicarp**). The number of seeds within the stone can vary from 1 - 5, depending on the species. They are usually difficult to separate from the stone and so the whole stone is used for sowing. This type of fruit is called a **drupe**. Examples are paingyo (1 seed), bakaino (4 seeds), lapsi (5 seeds)

5.6 Fleshy fruits without stones:

In this type, the seeds (usually many) become encased in flesh formed from the ovary, but no stone develops. Such fruits are called **berries**. Sometimes the skin is very thick (e.g. orange type fruits, called a **hesperidium**). In some fruits, the receptacle also swells up and forms part of the fleshy covering of the fruit (e.g. apple fruits, called a **pome**). The seeds can be removed from the flesh and are used as pure seed.



5.7 Other angiosperm fruits:

A distinct fruit type consists of a fleshy pericarp, which splits open when relatively dry, and exposes seeds which have a covering of jelly around them e.g. champ. Many fruits are made up of an aggregate of smaller fruits of the types described above e.g. Kimba. The fig fruit is distinct in that the fleshy part is the base to which the flowers are attached. Each female flower forms a tiny nut with one seed inside. If gall flowers are present in the fig, they form hollow seed-like nuts from which mature wasps hatch.

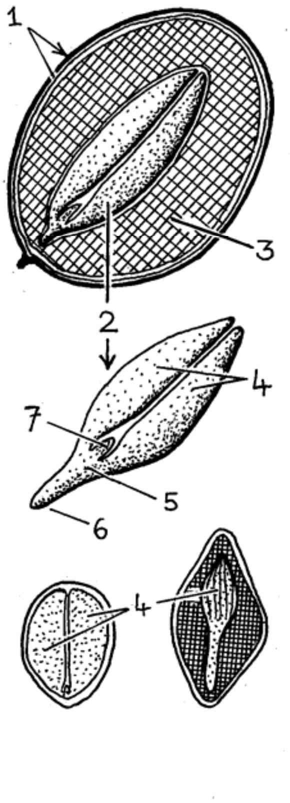
5.8 Conifer fruits:

For practical purposes, these fruits can be described as dry fruits which open. However, the structure is different. Most conifer fruits (cones) have a central axis around which many woody scales are attached. Two mature seeds are located on the top surface of the scales. These detach themselves once the cone is dry and the scales separate apart.

6 SEED DEVELOPMENT

6.1 Ovules to seeds:

While the ovary develops to form the fruit, the ovules also develop to form the seeds. Seed development of gymnosperms and angiosperms is slightly different, bit for practical purposes they are the same.

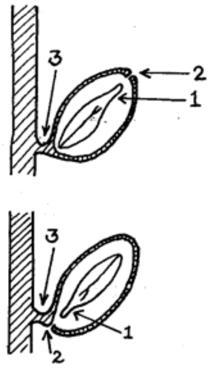


6.2 Seed parts:

The mature seed will generally comprise the following parts: (1) a protective seed coat, which is often made up of two layers: a hard outer coat (**testa**)and a papery inner one (**tegumen**); (2) within the seed, there will be the potential plant (**embryo**), formed from the fertilised ovum; (3) in some species, the embryo is small and surrounded by nutritive tissue (**endosperm**) - in other species, there is no endosperm, and the embryo fills the entire seed.

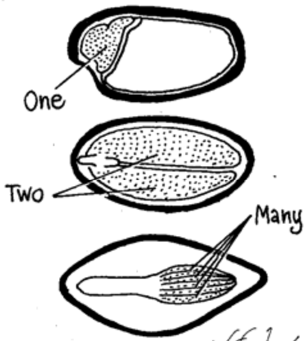
6.3 Embryo parts:

The embryo itself consists of: (4) seed leaves (**cotyledons**), which number 1,2 or many depending on the class of plant; (5) a short stalk (**hypocotyl**) to which the cotyledons are attached, which finishes in (6) a potential root (**radicle**); (7) sometimes visible at the other end is the growing point for further leaves (**epicotyl**). In seeds which have no endosperm, the cotyledons are large and fleshy. The shape of the embryo may be straight or quite convoluted. All parts are generally white or cream in colour, though some cotyledons may be greenish.



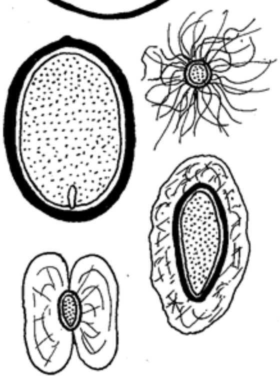
6.4 Orientation of seed and embryo:

The **radicle** (1) is normally at the end of the seed where the small opening (2) (**micropyle**) was located, and through which the pollen tube grew. The seed is attached to the ovary wall by a short stalk (3) (**funicle**). This stalk often joins the seed near to the micropyle, and leaves a scar or protuberance on the seed when it is detached. The radicle is usually therefore next to the end where the seed was attached to the fruit, but this is not always so.



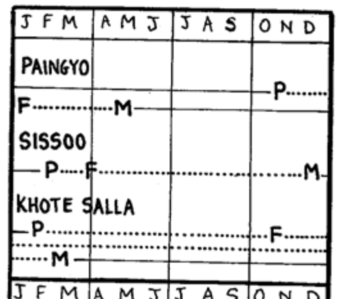
6.5 The cotyledons:

The cotyledons act as a food reserve in seeds with no endosperm, and are thick and fleshy and consist of most of the tissue within the seed. In seeds with endosperm, the cotyledons are smaller, thinner and generally act like leaves after germination, becoming green. As mentioned before, in angiosperms, the monocotyledons have 1 cotyledon (**scutellum**); the dicotyledons have 2 cotyledons, whilst in gymnosperms, the conifers usually have many cotyledons.



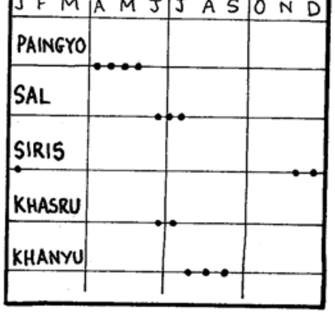
6.6 The testa:

The testa takes various forms. In some species it is relatively thin and easily permeable to water and air. In others, it becomes very hard and impermeable. Some species have seeds with a special outer layer that may be juicy (e.g. champ), or may form wing-like outgrowths (e.g. utis), or cotton like filaments (e.g. cotton). These outgrowths generally help in the dispersal of the seed as described later. Where possible, they are removed artificially for storage and sowing. Such parts should not be confused with fruit parts (e.g. stones).



6.7 Time taken for maturity:

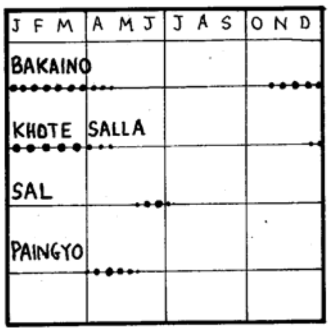
The time taken between fertilisation (F) and fruit/seed maturity varies considerably between species. In some species (e.g. paingyo) it may take a few weeks; in others a few months (e.g. sissoo), whilst some require over a year for full development (e.g. chir pine).



7 FRUIT MATURITY AND SEED DISPERSAL

7.1 Fruiting seasons:

Many species have fruits that become mature just before the rains, so that when the seed is dispersed, it will soon encounter good conditions for growth (e.g. sal). Other species may mature early in the dry season, in which case the seeds must remain dormant until the rains begin (e.g. siris). Some species have fruits that mature during the ,monsoon (e.g. khasra) Species with dry fruits that open generally mature during the dry season.

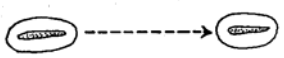


7.2 Duration of the season:

Individual fruits on the same tree will mature within a few weeks of one another. However, there is often a large difference between trees, such that the period during which fruits become mature may extend for a few weeks to several months. Once the fruits are mature, they may disperse their seeds very rapidly (e.g. bainsh), or the fruits and seeds may remain on the tree for many months (e.g.bakaino). The time and duration of ripening will depend on weather conditions - warmer weather generally speeds development so that fruits at lower altitudes ripen first.

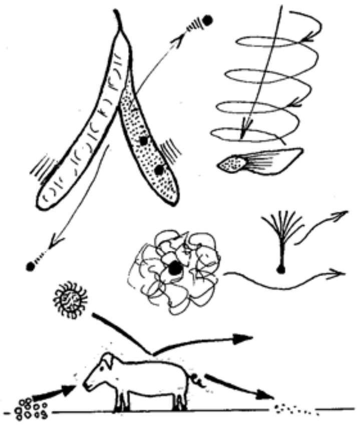
7.3 Maturity indicators:

Dry fruits that do not open are generally mature when they change colour from green to brown, and are about to fall off. Dry fruits that open show a similar change in colour, and are usually just about to open. Fleshy fruits are normally mature when the skin has changed from green to another colour. The seed within (for all fruit types) will generally be mature when the seed coat is dark, and the contents are white and firm.



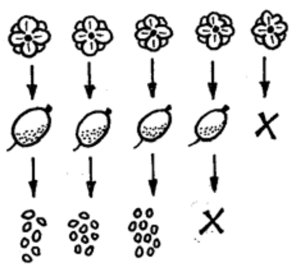
7.4 Immature seed:

Not all ripe fruits will contain mature seeds. Some species have seeds which only mature some time after the fruit has matured. This is further discussed in the paragraph on dormancy.



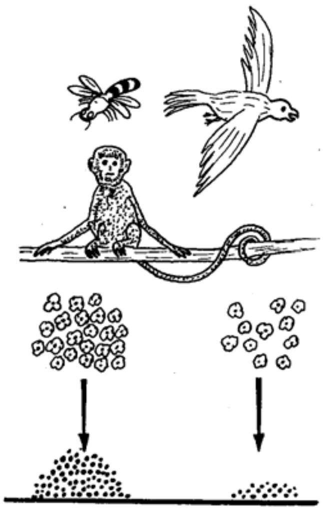
7.5 Methods of dispersal:

Once mature, the seed must be dispersed to a suitable place for its growth. The different fruit types are designed to ensure this dispersal, and act in different ways. Most dry fruits have seeds that are dispersed by mechanical action (e.g. pods that open suddenly); wind (seeds with wings or hairs); animal (fruits with burrs, acorns); water (floating seeds). Most fleshy fruits will be eaten by birds or mammals, so that the seed is distributed in the faeces, or rejected during feeding some distance from the parent tree. A knowledge of the method of dispersal can help in knowing how to collect, process and treat the seeds.



7.6 Abundance of fruit crops:

A fruit crop can only be as abundant as the flowering was, and is generally much less. Although flowers may begin to form fruits, many will not develop and fall off, due to various reasons. Weather may be an important reason: developing fruits need a lot of water, and if the weather is too dry, the fruits may fall; hail may knock off fruits; and frost can kill young fruits.

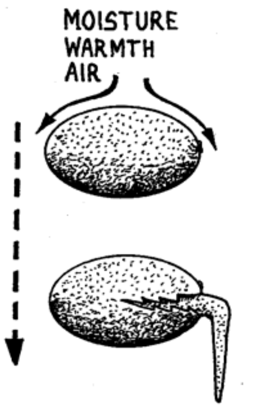


Pests can reduce the crop: insects, birds or mammals may eat the fruit or seeds before they are fully mature. Obviously, man is important too, and may destroy the fruits while cutting trees for fodder, for example.

7.7 Fruit crop quality:

It is a general rule that the more abundant the fruit crop, the better the seed within. Due to improved pollination, there will be more viable seed per fruit, fewer empty seed, and proportionately less damage from pests. Thus it is always best to concentrate collections in good crops. Seed will be better and cheaper.

8 CONDITIONS FOR SEED GERMINATION

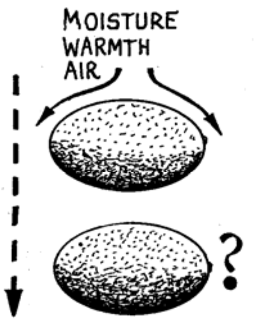


8.1 Resumption of growth:

Germination is the whole process during which the embryo within the seed resumes growth, and finally emerges from the seed.

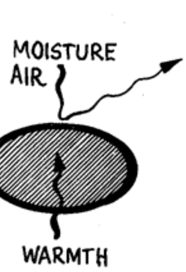
8.2 The basic requirements:

A seed and embryo must have several basic requirements before germination can start: (1) adequate moisture, (2) a sufficiently high temperature, (3) air, and (4) sometimes, but not always, light. Moisture is very important, as the developing embryo needs large quantities. If the temperature is too low, then the chemical processes cannot take place. Air is needed for respiration (described later). Light may be needed to trigger off germination, and is necessary for the growing seedling.



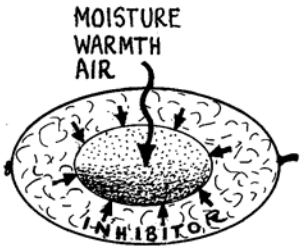
8.3 Dormant seeds:

Many seeds, once they have these requirements, will germinate readily. However, some will not and are said to be dormant. They will only germinate if further requirements are met. In nature, such additional requirements ensure that the seed can only germinate when adequate conditions are likely to continue for the growth of the seedling e.g. at the beginning of the rains.



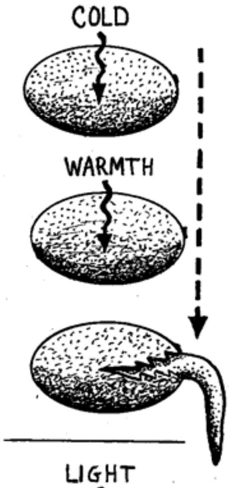
8.4 Seeds with hard coats:

Many species have seeds with hard coats that are impermeable to water. However, after a sufficient time in the soil, with warmth, moisture, and action of soil organisms, the coat becomes permeable, water can enter the seed, and then germination will begin. Such seeds are typical of the legumes (e.g. siris). The hard seed coat ensures that the seeds will germinate only when the rains have properly begun, and not after the odd shower of rain during the dry season.



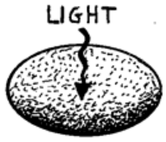
8.5 Chemical inhibitors:

Some species have fruits and seeds that contain a chemical which prevents germination starting, although the basic requirements are provided. In this case, the chemical mast be washed out or destroyed by natural processes before germination can start. The chemical may be in the fruit or seed coat. It is removed or destroyed in several ways: rotting of the fruit flesh; washing out by rain; passing through the gut of an animal; being heated by sun or fire. The chemical ensures that the seed will only germinate when conditions are correct for seedling growth, as with hard coated seeds.



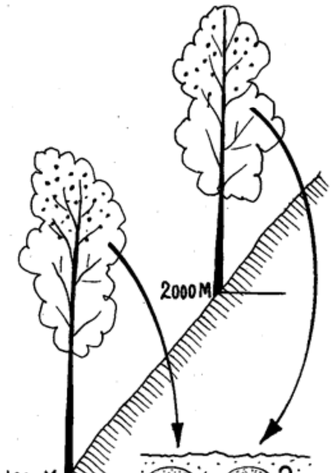
8.6 Immature embryos:

Some species have seeds with immature embryos at the time of dispersal. Most often, the seed must pass through a period of cold weather, while it is moist, before the embryo matures. Once a sufficiently long period of cold has passed, the seed will be able to germinate when warm weather arrives. Thus the seed is prevented from germinating during a warm spell in the middle of winter. Some species require a definite sequence of warm and cold temperatures before germination is possible. Other species simply require the seed to dry out for a long enough period so as to mature the embryo.



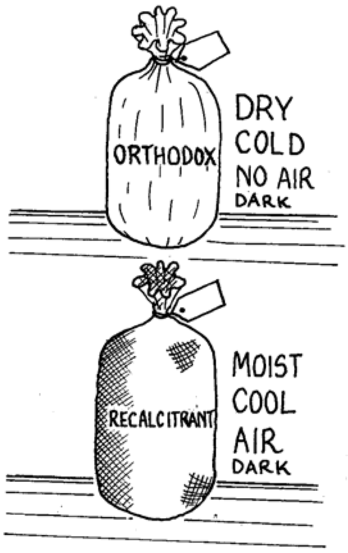
8.7 Other causes:

Light is sometimes important in triggering off germination, particularly in small seeds (e.g. Betula). In nature, this probably ensures that the seed only germinates when there is sufficient light to sustain growth.



8.8 Start of dormancy:

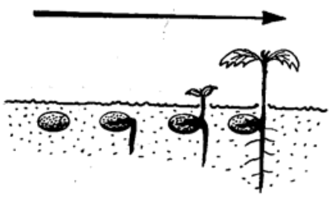
The amount of dormancy in a seed varies not only between species, but also between trees of the same species. It is sometimes caused by environmental conditions during the development of the seed. For example, trees growing at cooler, higher altitudes may show dormancy, whereas trees of the same species growing lower down do not show dormancy. Improper seed handling may make a seed dormant which is not usually so. Certain species have seeds that only show dormancy once the seed is fully developed. In this case, if the seed is sown just before becoming mature, it will germinate almost immediately (e.g. lankuri).



8.9 Maintaining viability:

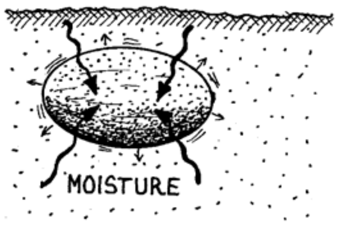
When stored artificially seeds can remain viable and ungerminated for much longer than they would normally under natural conditions. In general, viability is prolonged the more the basic requirements of moisture, temperature, air and light are reduced. However, some species have seeds that must remain sufficiently moist to maintain viability (recalcitrant seeds), and some of these must not become too cold. Most seeds can withstand drying and cooling (orthodox seeds). Under optimum conditions, recalcitrant seeds can remain viable for a few days or weeks (e.g. sal) to several months (e.g. oak), whereas orthodox seeds can remain viable for many years or more (e.g. pine, sins, sissoo).

9 GERMINATION



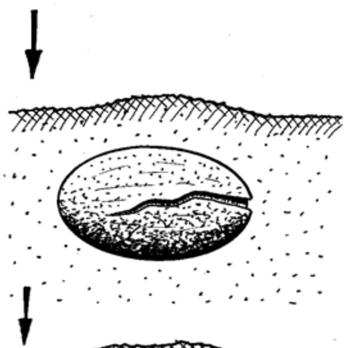
9.1 Seed to seedling:

Once all the necessary conditions of moisture, temperature, air, light, time and other requirements have been met, the seed will germinate and form a seedling as follows:



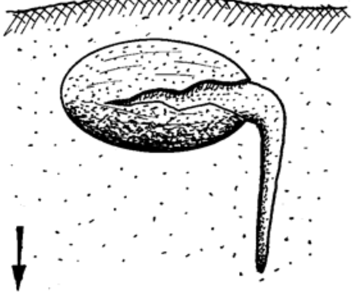
9.2 Initial activities:

The actual process of germination begins well before anything is visible to the naked eye. During this period there will be rapid adsorption of water, and certain chemical changes which are necessary before the embryo can start increasing in size. Nutrients present in the endosperm or cotyledons will begin to be absorbed by the embryo. It is important to note that once these processes have begun, they cannot be stopped without seriously weakening or usually killing the seed.



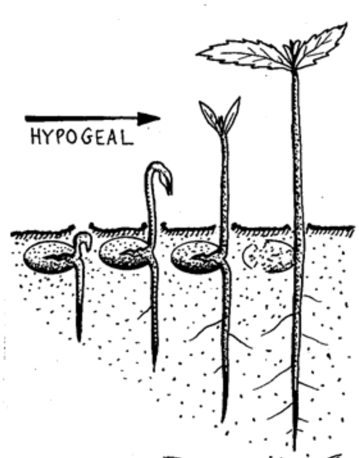
9.3 Splitting the seed coat:

Once the embryo begins to grow, the seed will swell and eventually split open. If the seed is surrounded by a hard pericarp (e.g. stone) this will also split. The seed coat will normally split at the end nearest to the radicle, which is the first part of the embryo to emerge.



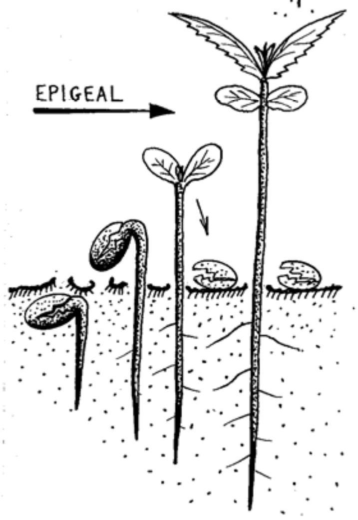
9.4 Growth of the radicle:

Immediately after the radicle emerges, it will bend downwards at the first opportunity and grow into the soil. This ensures that the seedling is securely anchored for further development of the upper parts, and that water can be absorbed as soon as possible. Once the radicle is established, further growth takes two forms:



9.5 Hypogeal germination:

In some species, the cotyledons remain on or below the ground, and the growing -point (epicotyl) above the cotyledons begins to grow rapidly, forming a shoot which is topped by rudimentary leaves (**plumule**). The plumule is bent backwards while the shoot emerges from the soil, but eventually turns towards the light and forms the first seedling leaves. During this period, the nutrients in the cotyledons are absorbed and eventually shrivel away. Thereafter, the seedling supports itself via the roots and the leaves which are green and able to photosynthesise e.g. oak.

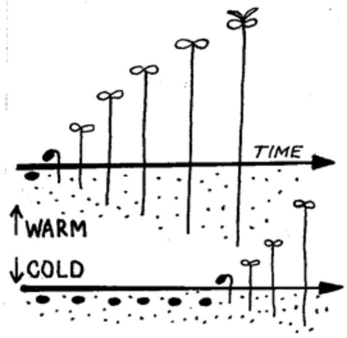


9.6 Epigeal germination:

In other species, the hypocotyl begins to grow rapidly once the radicle is sufficiently developed. This generally causes it to arch upwards out of the ground, eventually pulling the cotyledons, and often the seed coat, above ground. The hypocotyl then straightens and the cotyledons expand, turn green, and start to function as leaves. During this time the seed coat will have fallen off. Sometime after, the epicotyl will start to grow, and the plumule will develop to produce the first true leaves. If the seed has an endosperm, this is absorbed by the cotyledons during the initial growth.

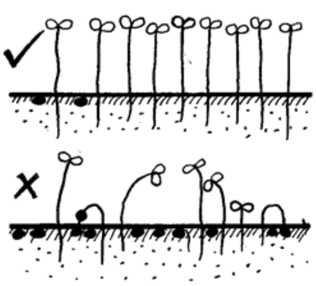
9.7Other types of germination:

Some species may show a slightly different type of growth to that described, particularly in the monocotyledons, such as grasses, onion, rice, wheat etc.



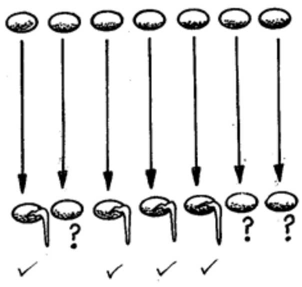
9.8 Speed of germination:

How fast seeds germinate depends on how good the sowing conditions are. The speed will tend to increase as temperature and moisture are increased. However, too high temperatures may weaken or kill the seed. Too much moisture may limit the supply of air. Under normal conditions, healthy seeds which are not dormant will begin radicle emergence after a few days to a few weeks.



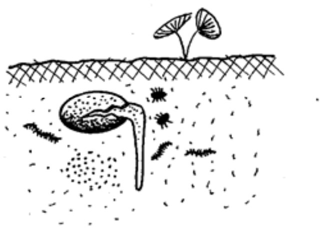
9.9 Vigour of germination:

Healthy seeds should germinate quickly and uniformly when sown in the nursery. However, adverse conditions during seed development, improper handling, or poor storage can weaken seeds so that they germinate more slowly over a longer period, and many of the seedlings may show abnormal behaviour. It is important to realise that seeds can be weakened in this way and that they must therefore be handled with care.



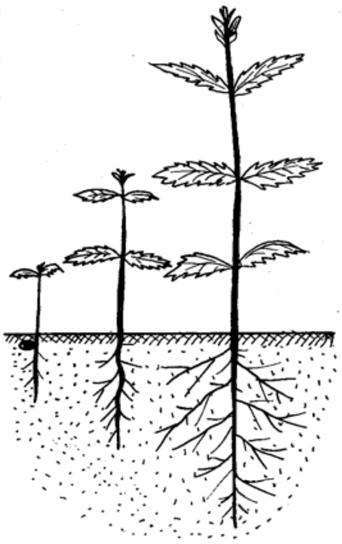
9.10 Germination percentage:

In any one seed lot, not all the seeds will germinate on sowing, and it is important to know why. The seeds which do not germinate may be dormant, too weak, dead, or empty. The dormant seed can be treated, and the empty seed can be removed. If many weak or dead seeds are present, the reasons should be determined. As a general rule, the lower the germination percentage, the lower the vigour of the viable seed (assuming empty seed removed, and dormant seed treated).



9.11 Mortality during germination:

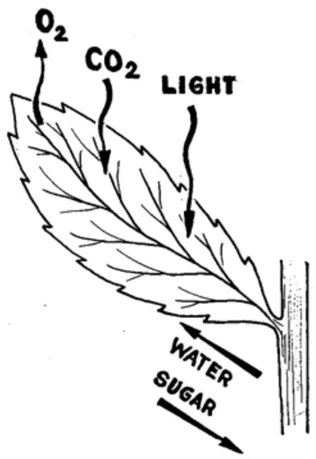
A germinating seed is very susceptible to pests etc. and many will die from being attacked by fungi, insects, or if the moisture is inadequate or excessive. For this reason, the germination percentage is usually lower in the nursery than in the laboratory, where such pests can be controlled. Chemicals used for controlling pests must be used carefully as the emerging radicle and epicotyl are very sensitive to toxic materials. In general, the more vigorous a seed is, the more resistant it is to these problems.



10 SEEDLING GROWTH

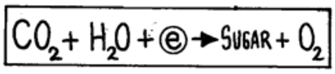
10.1 Seedling to sapling:

Once the store of nutrients within the endosperm or cotyledons has been exhausted, the seedling must depend on its roots and leaves to supply the necessary materials for growth. The medium in which the roots are growing must contain sufficient nutrients, and there must be adequate light to enable the leaves to photosynthesise materials. Here it is useful to summarise two important processes on which plants depend for growth and formation of further crops of seeds.



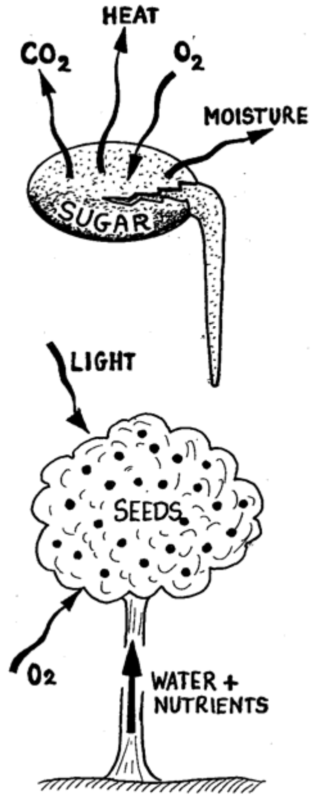
10.2 Photosynthesis:

The growth of a plant and formation of seeds requires an adequate supply of building materials. Raw materials such as water and soil nutrients are taken in by the roots, but they must be converted into more complicated raw materials. The manufacture of these materials begins in the leaves, to where the water and nutrients are transported in the inner sap (xylem). The basic process is as follows: The leaves absorb carbon dioxide gas from the air, and with the help of light energy, combine the gas with water to form a type of sugar. Oxygen gas is formed as a waste product (a very useful one!). In summary:-



carbon dioxide + water + light energy -> sugar + oxygen gas

The sugar is then combined with nutrients to form more complicated substances that are required by the plant. These are then transported to the growing areas in the outer sap

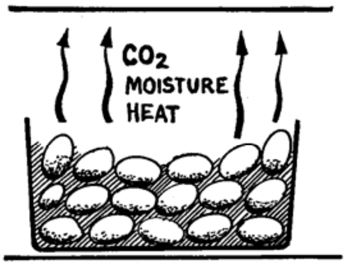


10.3 Respiration:

All the time the plant is alive, it not only requires building materials, but also energy to enable the various life processes to function. Part of the sugar made in photosynthesis is used as a fuel to provide this energy. The basic process is the reverse of photosynthesis. Sugar and oxygen (absorbed through the plant walls) are 'burnt' together, producing heat energy and waste products of carbon dioxide gas and water;

oxygen gas + sugar -> heat + carbon dioxide gas + water

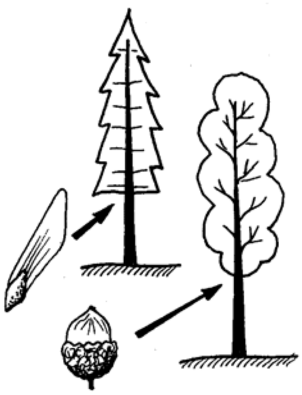
This process happens all over the plant in living tissues, but increases in areas of rapid growth. It is particularly high in germinating seeds. If insufficient oxygen is present, then fermentation may occur, which produces alcohol instead of water, which damages the plant.



10.4 Importance for seeds;

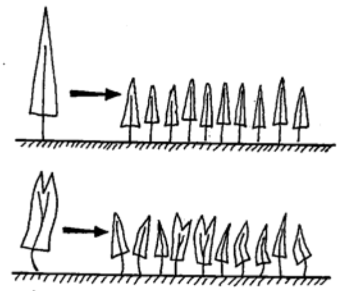
Photosynthesis will provide all the materials and food stores from which fruits and seeds are made. A healthy plant, with plenty of sun, air, water, and nutrients will therefore be in a better position to form fruits and seeds. During storage of fruits and seeds, a certain amount of respiration continues, and therefore care mast be taken to control the heat, gas and water produced. When germination starts, it will be obvious that plenty of oxygen is needed, so air must be provided besides water, warmth, etc. If oxygen is not supplied during growth, then alcohol may be produced, killing the seed.

11 INSTRUCTIONS FOR GROWTH



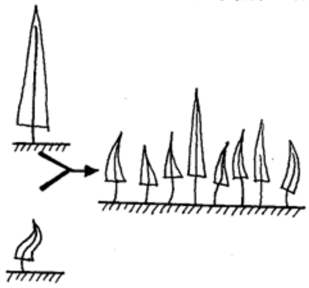
11.1 Pine seed to pine tree:

The seed embryos of different species look very similar, but when they develop into a seedling, they will be of the same species as the parent. This is because the embryo cells contain instructions or 'blueprint' for growth which is unique to each species. These instructions can be imagined as a book (**genotype**) with many pages (**chromosomes**) on which are written innumerable instructions (**genes**).



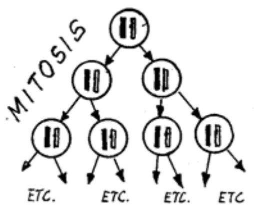
11.2 Quality control:

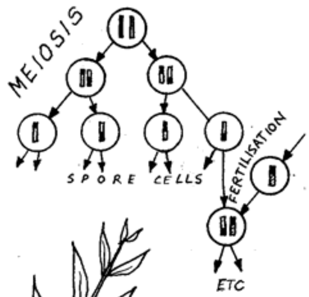
The genes not only control the basic form of the species, but also general characteristics such as whether the tree is naturally growing fast, or 'has a straight stem, or has dense wood. There are usually several genes which control a particular characteristic. Which ones are used by the plant, and when, depends on certain rules which will not be discussed here.



11.3 Parents and offspring:

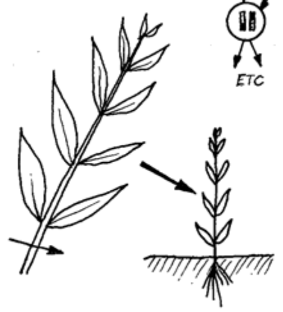
When an ovum is fertilised, the gene sets from both male and female parents are incorporated into the same cells. Thus the characteristics of the embryo, seedling and finally the tree will be determined by both parents. Which genes are in control depends on certain rules. Some characteristics may be emphasised, whereas others are suppressed.





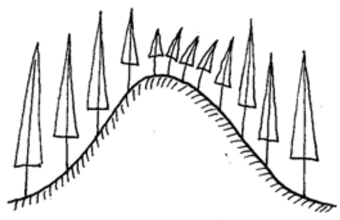
11.4 Cell copying:

Every time a cell divides the 2 gene sets (one from each parent) are copied to the new cells by a process called **mitosis**. An exception occurs when cells divide to form spores. In this case, the process (called **meiosis**), involves two cell divisions, ending up with 4 spore cells. During the process, genes are interchanged between sets, independently assorted, and reduced to one set per cell. Thus the 4 spore cells each have one different set of genes, made up from both parents. During fertilisation, the fusion into male and female gametes restores 2 sets of genes to further cells, made up from the 2 new parents, and the 4 'grandparents'.



11.5 Vegetative reproduction:

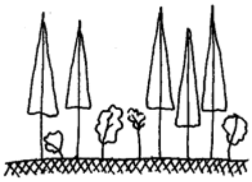
Since all cells (except spore cells) in a plant have the same genes, any one cell or group of cells could form a new plant by itself. Such an offspring is called a **clone** and is identical to its parent. To do this artificially, special techniques are required such as: **cuttings**; **grafts**; **layering** (which use large parts of the plant): and **tissue culture** (which uses a few cells). Plants can naturally reproduce themselves by this method, using such organs as **stolons**, **tubers**, **rhizomes**, and **suckers**.



PHENOTYPE = GENOTYPE X ENVIRONMENT

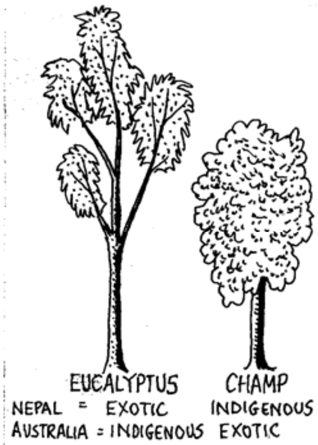
11.6 Environment:

The actual appearance (**phenotype**) of the seedling, tree or cutting will depend not only on the sets of genes provided by both parents (**genotype**), but also on the influence of the environment. For example, a naturally fast growing tree may, in fact, be slow growing because it is growing on a poor site. It is important to remember this relationship when selecting seed trees.



11.7 Natural selection:

Species may occur over a wide range of environments, some of which will be more suitable for their growth and reproduction than others. When this happens naturally, those species that are best adapted to a particular environment will tend to thrive, whereas those that are not will tend to die out.

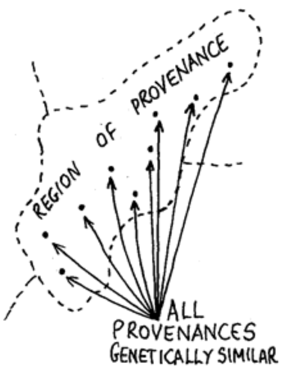


11.8 Indigenous and exotic species:

Indigenous species are those that occur naturally within their particular environmental area. Exotic species are those that have been introduced by man into an area where they have not been previously present. When this is done, care should be taken to ensure that the environmental conditions of the planting site match the original site where the species naturally grew. Otherwise the species may not be properly adapted to grow in its new site. This is particularly important for seed production, as small changes in the environmental conditions may prevent formation of flowers or production of fruits with viable seeds inside.

11.9 Provenances:

Many species will be found growing over a wide variety of environmental conditions, and will be well adapted to all of them. In this case, although the species will be the same, its genetic make-up will vary from place to place, as only those genotypes most suited to a particular environment will predominate. Thus it is important to know the exact place, or **provenance**, where the trees that produce seeds are growing, as this will give an indication of the genetic quality of the seeds, and how well the seedlings will be adapted to their new plantation sites.



11.10 Regions of provenance:

By studying the environmental conditions within which a species is found, and analysing provenance trials of the species, it may be possible to define regions within which all provenances will provide seed of similar genetic quality. If this is done properly, then any seed source within the region will provide plants that will give similar performance on a given plantation site.